Water and the Critical Need for a Thermal Band on Landsat

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"When the well runs dry, we shall know the true worth of water."

- Benjamin Franklin

At first glance, there seems to be little connection between a thermal imaging instrument on a satellite and importance of water to the western United States, but they are in fact related. Fresh water is a critical resource in the American west, and Landsat thermal image data are critical to understanding how much and where that fresh water is used, in particular by irrigated agriculture and urban landscaping. Irrigation requires a lot of water.

The United States has more than 50 million acres of irrigated agriculture. Residential and commercial landscapes and golf courses cover an additional 32 million acres. 'Irrigated Landscape' ranks as the largest irrigated 'crop' in the U.S. The total volume of water consumed by agricultural and landscape irrigation in the U.S. is estimated to be approximately 50 trillion gallons per year.

Irrigation is the largest user of fresh water in the western U.S., and Landsat thermal data is the basis of the best and least expensive way to quantify and locate where water is used and in what quantity. Unfortunately, we are in dire peril of loosing thermal data on future Landsat satellites, and therefore the ability to know how much water is used by irrigation and where it is used.

NASA launched the first Landsat in 1972, which makes Landsat the world's longest continuous program to collect digital multispectral data of the earth from space. Landsat 4, launched in 1982, was the first of the Landsat series to carry a thermal band, and each successive Landsat has had a thermal capability.

In 1992, the Congress and White House agreed to fund the procurement of Landsat 7. The Land Remote Sensing Policy Act of 1992 (Public Law 102-555) designated NASA and the U.S. Geological Survey as the agencies responsible for managing Landsat 7, and directed them to study options for a follow-on to Landsat 7. A major purpose of the Act was to ensure Landsat data continuity.

The Act defined 'data continuity' as:

> …the continued acquisition and availability of unenhanced data which are, from the point of view of the user – (A) sufficiently consistent (in terms of acquisition geometry, coverage characteristics, and spectral characteristics) with previous Landsat data to allow comparisons for global and regional change detection and characterization; and (B) compatible with such data and with methods used to receive and process such data.

Thermal data have been a key Landsat component beginning with Landsat 4 in1982. The Landsat data archive has more than 20 yeas of thermal imagery. The continuation of thermal imaging aboard future Landsats, besides being critical for water resources management, is part of the Landsat Data Continuity Mission (LDCM), which is fully covered by the mandate of PL 102-555 as cited above. The NASA science web site (http://science.hq.nasa.gov/missions/satellite_56.htm) makes an important point: "…the next Landsat satellite system needs to launched as soon as possible in order to minimize risks to data continuity."

The University of Idaho (UI) and the Idaho Department of Water Resources (IDWR) study water use by producing maps of evapotranspiration using Landsat data and the METRIC evapotranspiration model. Evapotranspiration, which is usually abbreviated as 'ET', is the process by which liquid water is converted into water vapor by evaporation from soil and transpiration by vegetation. ET is synonymous with 'water use' and is measured as a depth of water, for example 'The ET requirement for alfalfa in eastern Idaho is 36 inches per year'. METRIC is an acronym for Mapping ET at high Resolution using Internalized Calibration, and is an outgrowth of a European ET model called SEBAL.

UI and IDWR have been applying Landsat thermal data with METRIC since 2000. IDWR has used Landsat and METRIC to quantify water rights, estimate depletions from ground-water aquifers, facilitate water-rights transfers, and calibrate ground-water models that are linked to climate models. UI has partnered with users in New Mexico, California, Montana, Florida and Spain as well as collaborated with a commercial firm, SEBAL-North America that makes extensive applications in the western U.S.

The use of METRIC, SEBAL and other processes that rely on Landsat's visible, near infrared, and thermal data, are substantially more accurate than are simpler ET methods that use vegetation indexes, which are a combination of the visible and near infrared spectrum only. The advantage of using thermal data in mapping water use is that land surface temperature can identify fields that are short of water and thus have suppressed ET. This information is important to quantify actual water use by both irrigated agriculture and urban landscaping.

METRIC uses the high resolution data available from the two Landsat satellite systems that are still flying (Landsat 5 and Landsat 7), and from the archive of the now-defunct Landsat 4. Landsat is the only satellite system that provides continuous high resolution thermal images as a complement to visible and short-wave images. In this context, 'high resolution' means pixels that are 120 meters or less on a side.

The quantification of water use from Landsat using thermal data is the only way to independently and consistently measure water use on a field-by-field basis over large land areas. Typical field sizes in the U.S. range from 10 to 160 acres, or about 180 meters to 750 meters on a side. These sizes require relatively high resolution images to produce information on an individual field. Actual consumptive use of water is needed if misuse of water is to be proved or water scarcity confirmed, and generally this needs to be done on a field by field basis. The quickest and least expensive way to determine actual consumptive use is from high resolution thermal data that is collected at the same time as visible data. Landsat thermal data are the foundation for the only practical, useable method that western states will be able to use to compute and map actual water use. However, this option is about to disappear.

Two Landsat systems are still functioning, but just barely. Landsat 5, launched in 1984, is still extant, but has experienced repeated system failures and may very soon become inoperable. The other, Landsat 7, launched in 1998, was damaged in 2003 and its usability for ET determination is substantially impaired.

For most of the history of the Landsat program, two Landsat systems have been recording data simultaneously. Two fully-functioning Landsat systems, both recording thermal data, are needed to maintain the historical data flow.

A thermal imager is a critical component of the Landsat system for determining evapotranspiration. Use of the thermal band of Landsat permits the calculation of a full surface energy balance that identifies irrigated units that have reduced ET that can not be identified using short-wave bands alone.

A high resolution thermal imager similar to that contained on past Landsat systems must be included on any proposed future Landsat system. The lack of a thermal imager on the next Landsat satellite will substantially impair the abilities of water management entities to determine water consumption from irrigated agriculture and urban landscapes, to resolve water resource disputes, to mitigate impacts of water resource consumption, to implement, monitor and evaluate water conservation programs, to facilitate transfers of water rights, and to manage water resources in total. Other, existing satellites with thermal bands will not substitute for Landsat.
Other satellites have thermal capability, but are not and cannot be used in place of Landsat. The resolution of the MODIS thermal imager at 1,000 meters on a side is too coarse for use in determining ET from individual fields and within city environments. The ASTER satellite, with a smaller pixel size, has inconsistent return times, too few daily images collected, and a minimal data archive.

The Idaho Department of Water Resources has more detailed information on how Landsat thermal data are being applied to western water issues at:
http://www.idwr.idaho.gov/gisdata/et.htm.

More information on the University of Idaho ET mapping program is available from:
http://www.kimberly.uidaho.edu/water/metric/index.html.

April 25, 2006